FINAL REPORT

NATIONAL AERONAUTICS & SPACE ADMINISTRATION

SPACE SUIT VENTILATION VALVES

CONTRACT NO. NAS 9-7646

CCC P/N 2098 001-1

Prepared by Carl Naab

CARLETON CONTROLS CORPORATION

East Aurora, New York

September 29, 1969

NASA CR 101936

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SUMMARY

This final report summarizes Phase "D" of the contract which is the final part of the space suit ventilation valve program. This last phase consisted of fabricating and testing two sets of hardware. The units have since been forwarded to NASA.

During this final hardware phase the design improvement and changes from phases "B" and "C" were incorporated into the units. The major change consisted of enclosing the capsule assembly within an aluminum housing.

Two problem areas arose while incorporating the housing around the capsule. These were weight and pressure drop.

Weight: The initial design objective for the capsule assembly alone was 1.0 lb. max. The actual weight of the assembly was .71 lbs. When the housing was designed, its weight was calculated at .48 lbs. This gave a total of 1.19 lbs. and 1.2 lbs. was requested as the weight limit.

After the first housing was machined, it weighed approximately .62 lbs. A weight study showed that certain areas could be reduced or thinned down in cross section. This was accomplished and the housing weight was reduced to .52 lbs. This gave a total weight of 1.23 lbs. and a deviation was granted for this weight.

Pressure Drop: The pressure drop limit for the vent valve is .1 inches of H_2O. The two vent valves have an actual pressure drop of .4 and .45 inches of H_2O. Early in the program this discrepancy was suspected and NASA was notified that we could in no way meet the requirement of .1 inches of water. (It can be shown by calculations that the entrance and exit area alone have a drop of .1 inches of water). Based upon the above a "best design effort" was followed with the results as noted above.

Some additional testing was conducted concerning pressure drops. These consisted of back-flowing the unit (out to in) and checking the unit during the initial assembly cycle i.e. capsule threads just started into housing threads, to determine how much drop was attributed to housing configuration vs. throat area.

It was noted that the pressure drop was slightly less in the reverse direction. The units tested out at .35 and .40 respectively. The second part of the study showed that the pressure drop was independent of throat adjustment and was mainly due to internal fixed passageways.

CARLETON CONTROLS CORPORATION

CALCULATIONS INDEX

W.O. # 2098 DATE 12-27-67 BY G. ORD

CALCULATION # 1

PURPOSE: TO FIND ORIFICE DIA. (d_{ot}) REQ'D. FOR 6-ACFM FLOW OF OXYGEN WHEN: INLET (P_1) = 3.7 PSIA; TEMP. = 77°F AND ΔP ACROSS ORIFICE = 0.2 IN. H_2O (REF. ¶ 4.3 OF WORK STATEMENT)

RESULT: d_{ot} = 0.695-IN. (MINIMUM)

CALCULATIONS:

$$(d_{ot})^2 = \frac{\dot{w}\sqrt{RT}}{6.3\, C_d\, P_1 \sqrt{\frac{K}{K-1}\left[(P_2/P_1)^{2/K} - (P_2/P_1)^{\frac{K+1}{K}}\right]}}$$

$\dot{w}$ = FLOW (LB/SEC OF $O_2 \simeq$ 6 ACFM) = .0020505

R = 48.29

T = 77°F = 537°R

C_d = 0.65

P_1 = 3.7 PSIA

P_2 = 3.7 − 0.2(.03613) = 3.7 − .007226 = 3.69227 PSIA

K = 1.399

$$\sqrt{\frac{K}{K-1}} = \sqrt{\frac{1.399}{.399} = 3.50627} = 1.87250$$

$$2/K = \frac{2}{1.399} = 1.42959$$

$$\frac{K+1}{K} = \frac{2.399}{1.399} = 1.71480$$

$$(P_2/P_1) = \frac{3.69227}{3.70} = .997911$$

$$(P_2/P_1)^{2/K} = (.997911)^{1.42959} = 0.99700$$

$$(P_2/P_1)^{\frac{K+1}{K}} = (.997911)^{1.7148} = 0.99642$$

CARLETON CONTROLS CORPORATION CALCULATIONS WORKSHEET # 3B

W.O. # 2098 DATE 12-27-67 BY G. ORD

CALCULATION # 1 (CONT.)

PURPOSE: SEE SHEET #2

RESULT: $d_{ot} = 0.695$-IN.

CALCULATIONS:

$$\sqrt{(P_2/P_1)^{2/k} - (P_2/P_1)^{\frac{k+1}{k}}} = \sqrt{.99700 - .99642} = \sqrt{.00058}$$

$$= .0240831$$

$$(d_{ot})^2 = \frac{(.0020505)\sqrt{(48.29)(537)} = 259\,31.73}{(6.3)(.65)(3.7)(1.87250)(.0240831)}$$

$$= \frac{(.0020505)(161.033)}{683.266 \times 10^{-3} = 6.83266 \times 10^{-1}} = 3.30198 \times 10^{-1}$$

$$d_{ot} = \sqrt{.483264} = .695172 \cong .695\text{-IN.}$$

CARLETON CONTROLS CORPORATION CALCULATIONS WORKSHEET # 3C

W.O. # 2098 DATE 12-28-67 BY G. ORD

CALCULATION # 2

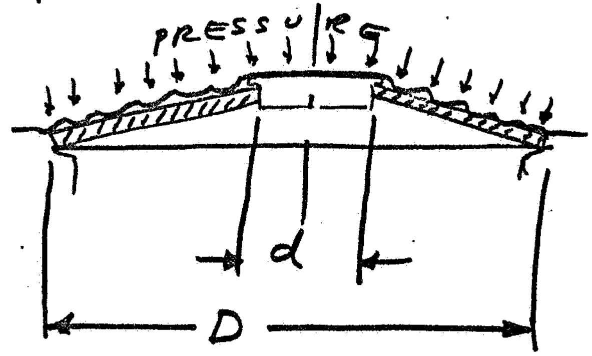
PURPOSE:

TO FIND EFFECTIVE AREA (Aea) OF SENSING ANEROID.

RESULT: Aea = 4.471-IN.^{2} EFFECTIVE AREA.

CALCULATIONS:

$$Aea = \frac{1-N^3}{3(1-N)} \cdot \frac{\pi}{4} D^2$$



$$N = \frac{d}{D} = .241379$$

$$D = 3.625$$

$$d = .875$$

$$N^3 = .0140637$$

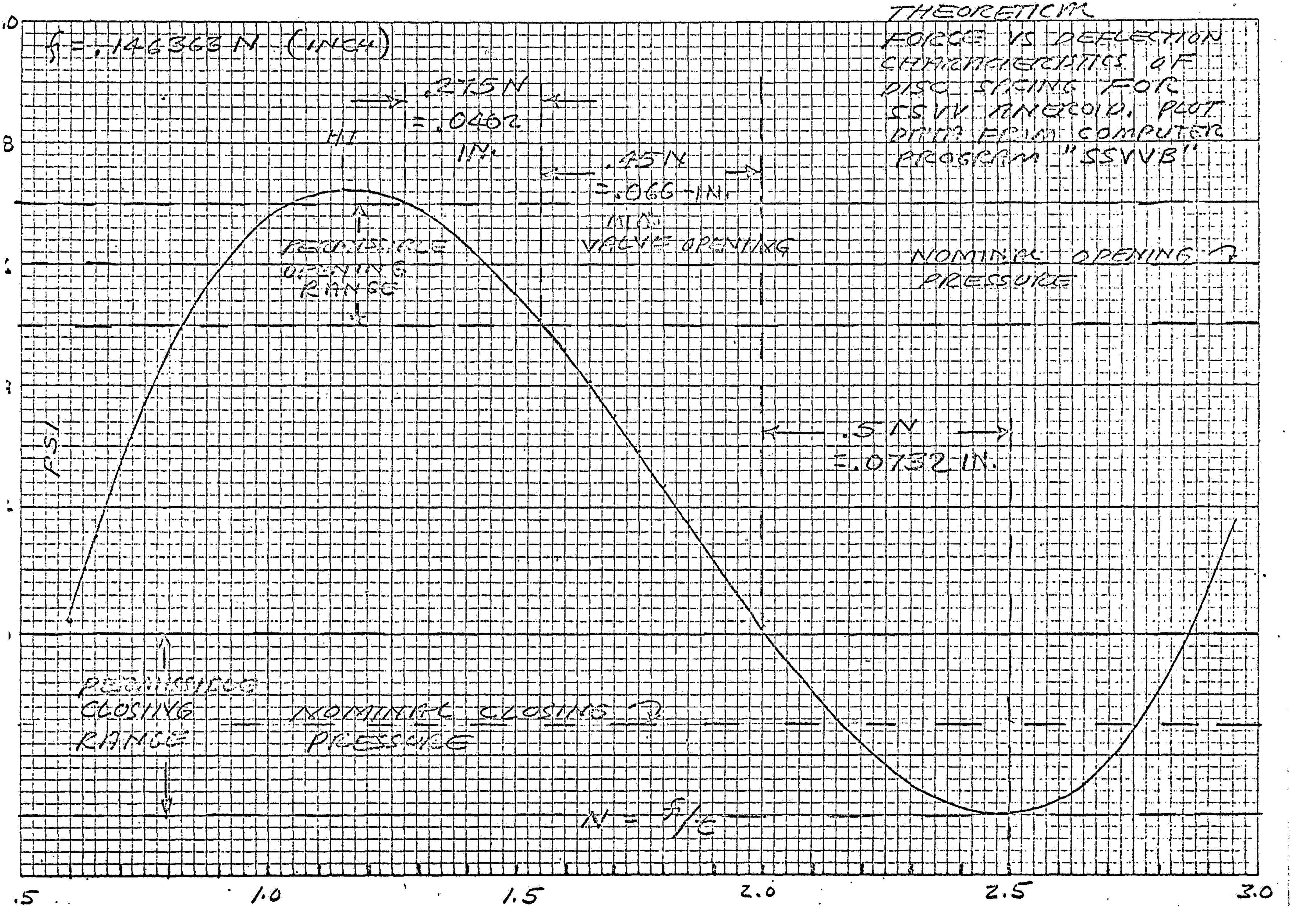
$$\frac{1-N^3}{3(1-N)} = \frac{.9859363}{3(.7586206)} = \frac{.9859363}{2.275862} = .4332144$$

$$Aea = (.4332144)(.7853982)(3.625)(3.625)$$

$$= (.3402458)\ D^2$$

$$= 4.47104$$

$$Aea \cong \cancel{4.7}\ 4.471-IN.^2$$


THEORETICAL
FORCE VS DEFLECTION
CHARACTERISTICS OF
DISC SPRING FOR
SSVV ANEROID. PLOT
DATA FROM COMPUTER
PROGRAM "SSVVB"
f = .146363 N (INCH)
.275N
= .0402
IN.
H1
.45N
= .066 IN.
MIN.
VALVE OPENING
PERMISSIBLE
OPENING
RANGE
NOMINAL OPENING P
PRESSURE
.5N
= .0732 IN.
PSI
PERMISSIBLE
CLOSING
RANGE
NOMINAL CLOSING P
PRESSURE
N = f/e
10
8
.5
1.0
1.5
2.0
2.5
3.0

W.O. # 2098 DATE 12-28-67 BY G. ORP

CALCULATION # 3

PURPOSE: TO FIND DIA. OF HOLE HAVING SAME AREA AS EFFECTIVE SENSING AREA OF PRESSURE SENSING ANEROID.

$= D_{Hea}$

RESULT: $\boxed{D_{Hea} = 2.386\text{-IN.}}$

CALCULATIONS:

$$A_{Hea} = A_{ea}$$

$$A_{Hea} = \frac{\pi}{4}(D_{Hea})^2 = A_{ea} = 4.471\text{-IN.}^2$$

$$(D_{Hea})^2 = \frac{4.471}{.7853982} = 5.69270\text{-IN.}^2$$

$$\boxed{D_{Hea} = 2.386\text{-IN.}}$$

CARLETON CONTROLS CORPORATION CALCULATIONS WORKSHEET # 3E

W.O. # 2098 DATE 12-28-67 BY G. ORD

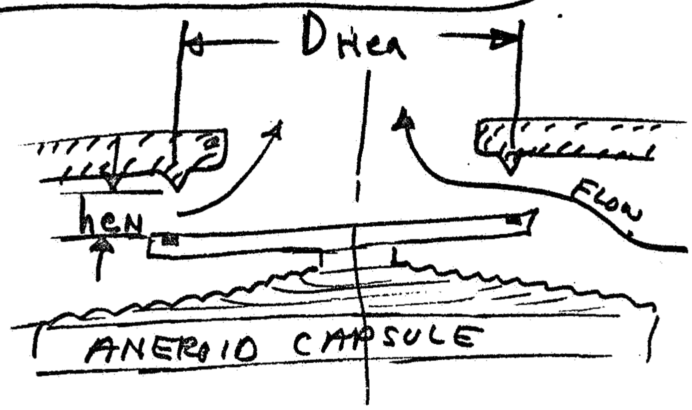
CALCULATION # 4

PURPOSE: TO FIND MINIMUM REQUIRED ANEROID VALVE LIFT (h_{eN}) IF EXIT ORIFICE DIA = D_{Hea} = 2.386-IN. DIA AND REQUIRED EFFECTIVE AREA FOR FLOW = 1.75-IN.^{2} = $\frac{\pi}{4}(d_{eo})^2$ = A_{oe}

RESULT: $\boxed{h_{eN} = .2335\text{-IN. LIFT REQUIRED}}$

CALCULATIONS:

$$\frac{\pi}{4}(d_{eo})^2 = 1.75$$



$$(d_{eo})^2 = \frac{1.75}{\pi/4}$$

$$h_{eN} = \frac{(d_{eo})^2}{4(D_{Hea})} = \frac{(1.75)}{\pi/4} \cdot \frac{1}{4 D_{Hea}}$$

$D_{Hea} = 2.386$

$$h_{eN} = \frac{1.75}{\pi D_{Hea}} = \frac{1.75}{(3.1416)(2.386)}$$

$$\boxed{h_{eN} = \frac{17.5 \times 10^{-1}}{7.49584} = .233463\text{-IN.}}$$

CARLETON CONTROLS CORPORATION CALCULATIONS WORKSHEET # 3F

W.O. # 2098 DATE 12-30-67 BY G. ORD

CALCULATION #

PURPOSE: TO FIND MAX. COMPRESSIVE STRESS AT UPPER INNER EDGE OF BELLEVILLE

RESULT: 142,900 - PSI

CALCULATIONS:

$$S_a = \frac{(1.1)(3.43671)(1.01571)(2.9\times10^{7})(8.130026)}{(6.33686\times10^{3})}$$

$$= \frac{90.5306\times10^{5}}{63.3686}$$

$$= 142,863 \text{ - PSI}$$

$$\simeq 142,900 \text{ - PSI}$$

CARLETON CONTROLS CORPORATION — CALCULATIONS WORKSHEET # 3G

W.O. # 2098 — DATE 1-11-68 — BY G. ORD

CALCULATION # 6

PURPOSE:

RQD. RELIEF VALVE ORIFICE AT 2.7 PSIA SUIT, ZERO SUIT EXTERNAL, 6.0 LB/HR O_2 FLOW, 100 °F, $C_d = 0.65$

RESULT: $d_{tR} = 0.226$-IN.

CALCULATIONS:

$$\dot{\omega}_{air} = \frac{6.0}{3600} \times .952024 = 1.58671 \times 10^{-}$$

LB/SEC OF AIR

$$T = 460 + 100 = 560°R$$

$$C_d = 0.65$$

$$P_1 = 2.7 \text{ PSIA}$$

$$P_2/P_1 < .528 \text{ (SONIC)}$$

USING ECKEL FLOW CALCULATOR:

$$d_{tR} = 0.226\text{-IN.}$$

CARLETON CONTROLS CORPORATION CALCULATIONS WORKSHEET # 3H

W.O. # 2098 DATE 1-11-68 BY G. ORD

CALCULATION #

PURPOSE:

MAX. RELIEF VALVE LIFT RQD. IF ACTUAL ORIFICE = .560-IN. AND RQD. ORIFICE = 0.226-IN.

RESULT: h_R = .023-IN. MAX.

CALCULATIONS:

h_R = MAX. VALVE LIFT RQD. (IN.)
D_R = ACTUAL R.V. ORIFICE = .560-IN.
d_{ER} = .226-IN. = RQD R.V. ORIFICE

$$h_R = \frac{(d_{ER})^2}{4 D_R}$$

$$h_R = \frac{(.226)(.226)}{(4)(.56)} = \frac{.051076}{2.24} = .023\text{-IN.}$$

CARLETON CONTROLS CORPORATION CALCULATIONS WORKSHEET # 31

W.O. # 2098 DATE 1-11-68 BY G. ORD.

CALCULATION # 8

PURPOSE:

FIND EFFECTIVE SENSING AREA OF RELIEF VALVE USING .560-IN DIA. ORIFICE WHEN UNDER STATIC (NO FLOW) CONDITIONS

RESULT: 0.246301-IN.^{2} RELIEF VALVE SENSING AREA.

CALCULATIONS:

A_{RS} = EFFECTIVE SENSING AREA OF RELIEF VALVE (STATIC CONDITIONS)

D_R = DIA. OF RELIEF VALVE SEAT
= 0.560-IN.

$$A_{RS} = \frac{\pi}{4}(D_R)^2 = (.7853982)\overbrace{(.560)(.560)}^{.3136}$$
$$= .246301\text{-IN.}$$

CARLETON CONTROLS CORPORATION

EC. NUMBER	REVISION LETTER	PAGE 4

5.0 Quality Assurance

DATA SHEET

CCC P/N 2098 001 - 3

S/N 1

NASA P/N NAS 9 7696

Tested By A. Kempke

Date 9-18-69

NASA SPEC. ______

TEST	LIMITS	ACTUAL
4.1 Visual	No nicks, etc.	ok.
4.2 Opening Pressure	3.5 to 3.7 PSIA	3.6 PSIA
4.3 Closing Pressure	3.0 to 2.7 PSIA	2.85 PSIA
4.4 Pressure Drop	T.B.D.	0.4 "H_2O
4.5 Weight	1.3 LBS. MAX.	1.23 LB.

Quality Control (CA)

5.0 Quality Assurance

DATA SHEET

CCC P/N 2098 001 - 3 Tested By C. NAAB

S/N 2 Date 9-18-69

NASA P/N NAS9-7646 NASA SPEC.

TEST	LIMITS	ACTUAL
4.1 Visual	No nicks, etc.	ok
4.2 Opening Pressure	3.5 to 3.7 PSIA	3.65 PSIA
4.3 Closing Pressure	3.0 to 2.7 PSIA	2.85 PSIA
4.4 Pressure Drop	T.B.D.	0.45 "H_2O
4.5 Weight	1.3 LBS. MAX.	1.24 LB.

Quality Control

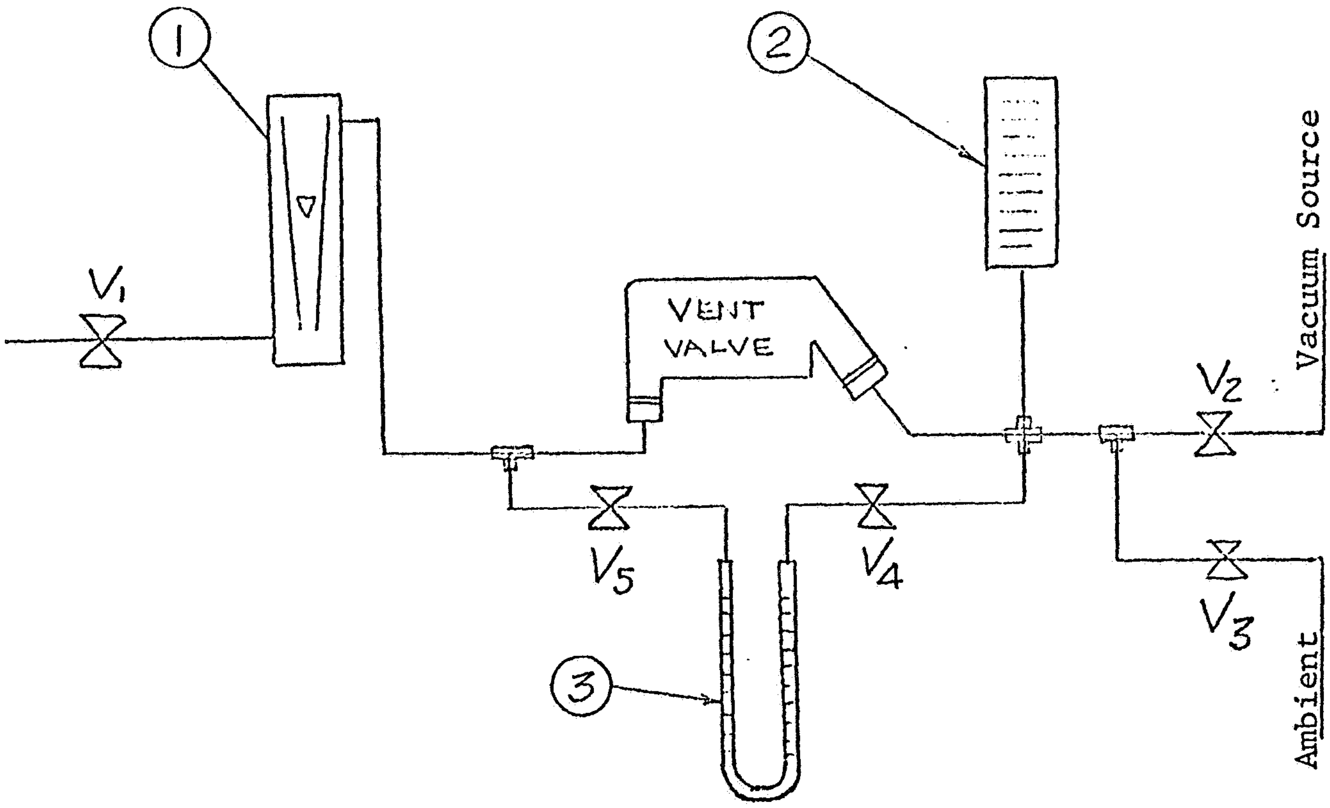


FIGURE I

Opening and Closing Pressure Tests

1. Flowmeter
2. Altitude Gage
3. H_g Manometer

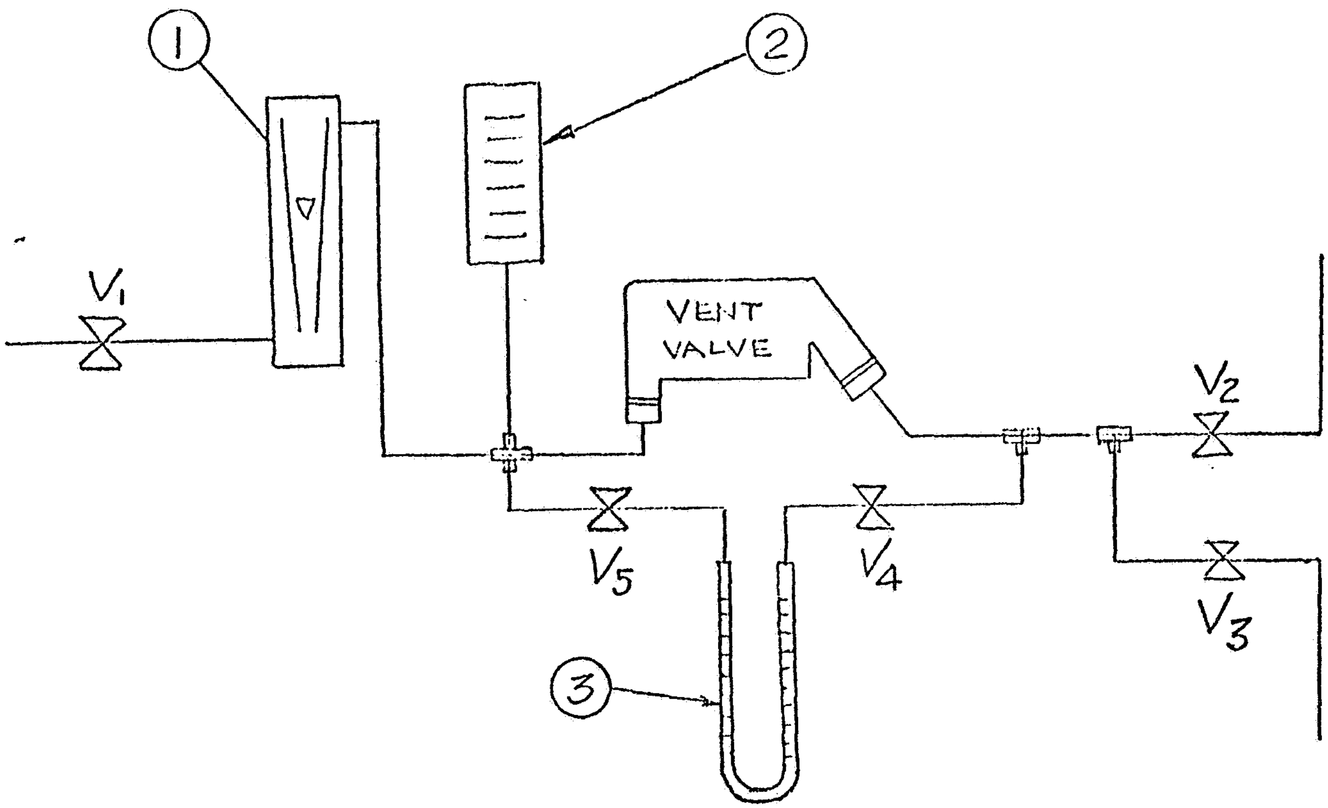
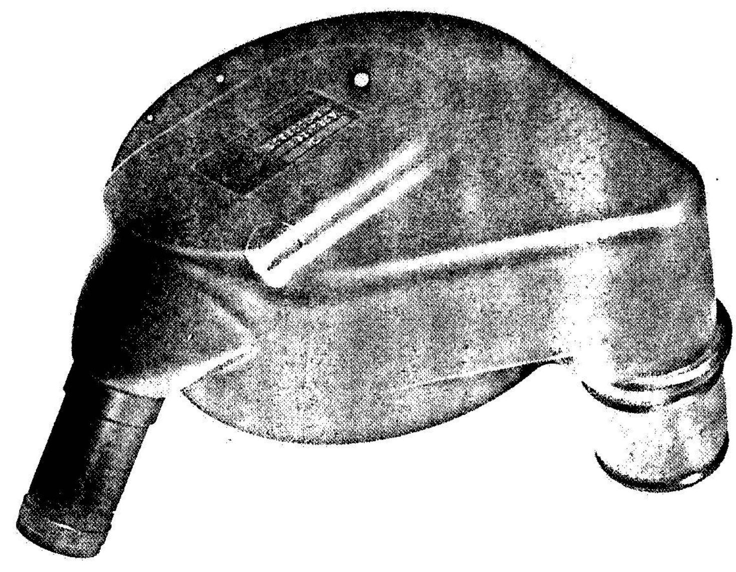


FIGURE II

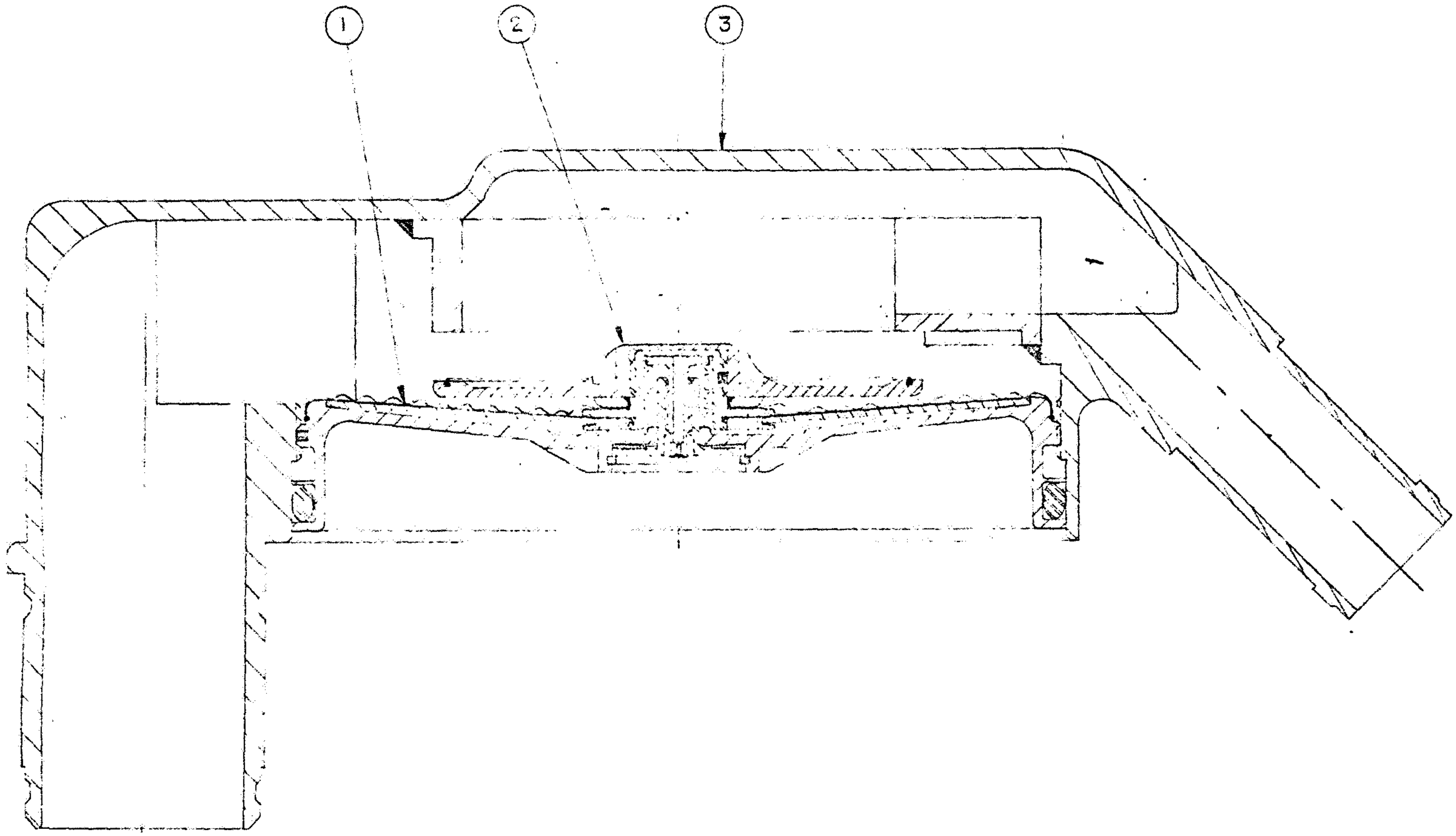
Pressure Drop Test

1. Flowmeter
2. Altitude Gage
3. H_2O Manometer



2098-001

VENTILATION VALVE



SEE SEPARATE PARTS LIST

NO. REQ'D	PART NO.	PART NAME	CODE IDENT.	SIZE	SPECIFICATION / MATERIAL
	2098 001-3	SPACE SUIT VENT VALVE			

ALL STRAIGHT SCREW THREADS PER MIL-S-7742 CLASS 3 (A OR B)

ALL TAPER PIPE THREADS PER MIL-P-7105

DRILLED HOLE TOLERANCES EXCEPT AS NOTED
.040 TO .125 DIA. + .002 − .001
.125 TO .228 DIA. + .003 − .001
.228 TO 1/2 DIA. + .004 − .001

ALL DIMENSIONS AFTER PLATING UNLESS NOTED

REMOVE BURRS AND BREAK SHARP EDGES .015 X 45° MAX.

MACHINE SURFACES 63/ RMS PER MIL-STD-10 UNLESS NOTED

ALL DIMENSIONS GIVEN IN INCHES
DIMENSIONAL TOLERANCES
±1/2° − ±1/64 − ±.005
.X .XX .XXX ANGLES
±.1 ±.03 ±.005 ±1/2°
UNLESS NOTED

FINAL PROTECTIVE FINISH

MATERIAL

LIST OF MATERIALS OR PARTS LIST

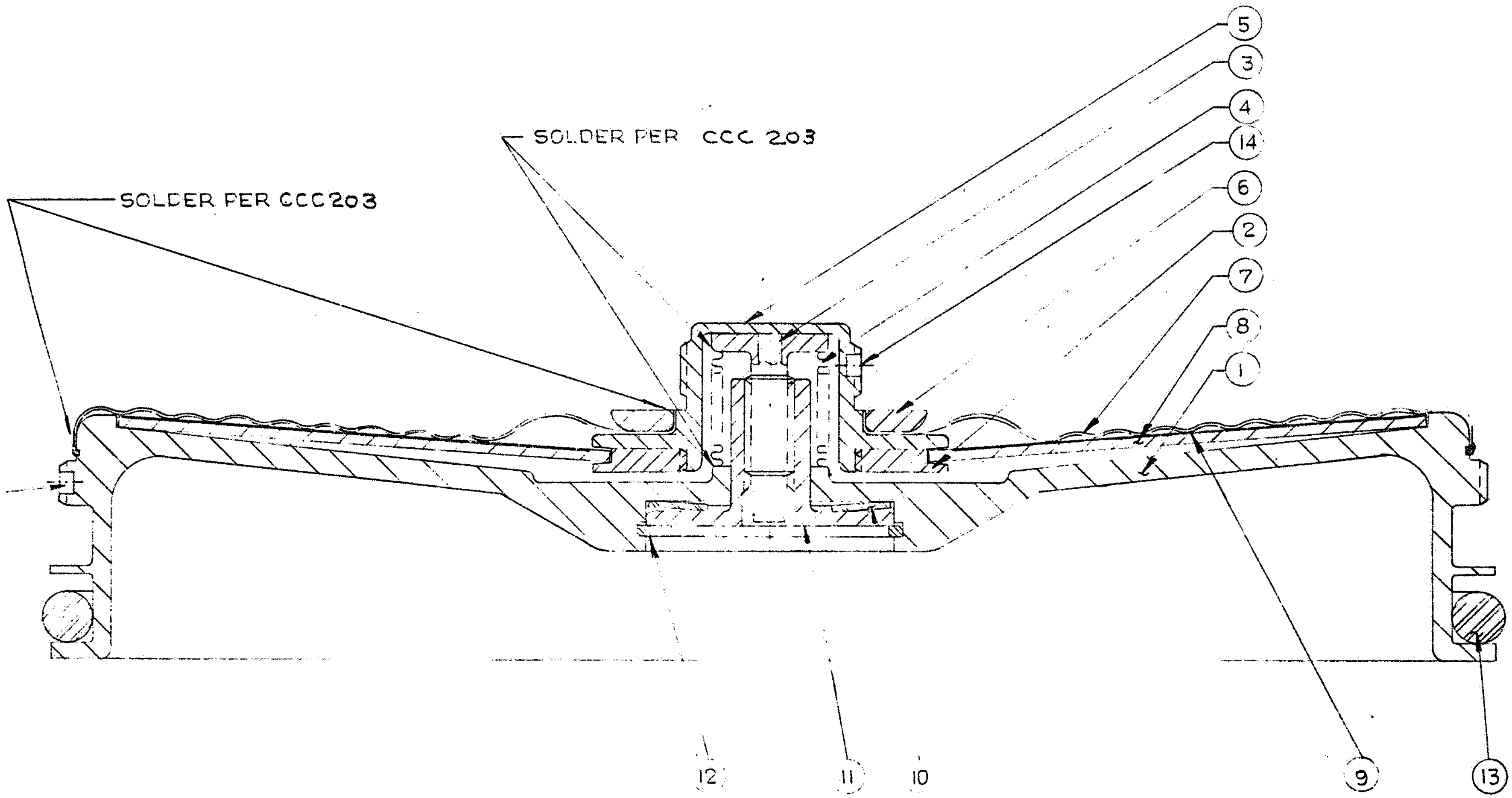
DRAWN BY	E.O'ROURKE	18 JUNE 69
DESIGN		
CHECK		
PROJ.	G. Ord	6-21 69
APPROVAL DESIGN ACTIVITY		

CARLETON CONTROLS CO

SPACE SUIT VENT VALVE

CODE IDENT. NO.		
04577	C	2098 50

SYM	DESCRIPTION



SEE SEPARATE PARTS LIST

	NO. REQ'D	PART NO.	PART NAME	CODE IDENT.	SIZE / MATERIAL	SPECIFICA
		2098 5011-3	CAPSULE ASSY.			

ALL STRAIGHT SCREW THREADS PER MIL-S-7742 CLASS 3 (A OR B)	ALL DIMENSIONS AFTER PLATING UNLESS NOTED	LIST OF MATERIALS OR PARTS LIST	
	REMOVE BURRS AND BREAK SHARP EDGES .015 X 45° MAX.	DRAWN BY E. O'ROURKE — 17 JUNE 69	CARLETON CONTROLS
	MACHINE SURFACES 63/ RMS PER MIL-STD-10 UNLESS NOTED	DESIGN	
ALL TAPER PIPE THREADS PER MIL-P-7105	ALL DIMENSIONS GIVEN IN INCHES DIMENSIONAL TOLERANCES ± 1/2° – ± 1/64 – ± .005; .X ± .1, .XX ± .03, .XXX ± .005, ANGLES ± 1/2° UNLESS NOTED	CHECK	CAPSULE ASSEM
		PROJ. [signature] 6-23-69	

FINAL REPORT

2098 003-3 RELIEF VALVE

DEVELOPMENT PROGRAM

NAS-9-7646 PHASE "D"

Prepared by L.H. Gill

SEPTEMBER 29, 1969

CARLETON CONTROLS CORPORATION

East Aurora, New York

DEVELOPMENT PROGRAM OBJECTIVES

The prime objectives of Phase "D" of contract NAS 9-7646 was as follows:

1) Redesign the Relief Valve envelope to permit installation of the unit into the space suit ventilation gas connector.

2) Redesign operating mode selection mechanism to permit smoother operation than the original 2098 003-1 Relief Valve.

3) Design a positive locking device, locking in each of the three operational modes making accidental valve actuation impossible.

4) Positive mode selection to be attained by tactile sense.

5) Reconfigure valve to new performance specification as follows:

a) Crack and reseat at 4.5 PSIG.

b) Flow rate of 3.6 lbs/hr at 5.0 PSIA when exhausting into vacuum.

c) Purge flow of 7.8 ± 2 lbs/hr at 4.0 PSIA when exhausting into vacuum.

Design: Carleton submitted a design proposal to Manned Spacecraft Center (M.S.C.) and as a result of subsequent discussion with M.S.C., resubmitted a modified design incorporating indicating detents in the selection mechanism. This design is detailed in Carleton assembly drawing 2098 503-3 and associated sub-assemblies and detail drawings.

Review of Performance vs. Objectives:

1) Achievement of the first objective presented no design problem, however, the acceptability of the results will have to be evaluated by M.S.C., since Carleton does not have a ventilation gas connector with which to perform an evaluation.

2) The second objective also appears to have been acheived. The objective is somewhat subjective, however, the objectional grating feeling of the original -1 valve is absent in the -3 valve. The manner in which the valve is rotated out of one mode position to the next has an effect on the "feel" of the indicating detents. Mode selection is accomplished by squeezing the two actuation buttons on the cover handle and simply rotating the handle to the desired position. Detents must be overcome to move out of any position. If the handle is pushed or pulled along the vertical axes of the valve, the detent "feel" becomes much stiffer. If the vertical force is large enough, it becomes impossible to rotate the handle. It is important to remember that squeeze and rotate are the only actions required to make a mode selection. Pushing or pulling is a hinderance rather than a help.

3) Radially moving locking pins, meets the third objective of a positive locking device. To unlock the mode selection handle the two red actuation buttons are squeezed. The handle is now free to rotate. As the handle is rotated out of the initial detent position, the buttons may be released, rotation can continue to the next position where the cover will automatically be locked in place. The buttons must again be squeezed to make the next selection.

4) Orientation of the mode selection handle gives the tactile clue to the operating mode in use. The nameplate on handle is marked to indicate the selected position and is used only to initiate the operators. After familiarization, identification of position is by tactile sense through the shape and position of the mode selection handle. The "L" shaped tab at the side of unit is provided to lock the unit in a permanent position so that orientation of the handle can have meaning.

5) The final objective of performance has not been completely met. The purge position flow at 4.0 PSIA meets requirements, however, spread of pressure between crack/reseat and full flow is slightly larger than the design goal of 0.5 PSI. Although the components had been sized to yield a .25 PSI spread between crack/reseat and full flow, the performance has not met this theoretical prediction. Some deviation from the theoretical performance was anticipated based on other similar relief valve design. Numerous component reworks were made to correct the condition, however, to no avail. It is Carleton's opinion, however, that the units as designed will perform its intended function.

CARLETON CONTROLS CORPORATION

SPEC. NUMBER	REVISION LETTER	PAGE
CFT 428		6

DATA SHEET

CCC P/N 2098 003 - 3 Tested By R. Karlinski

S/N 1 Date 9/30/69

TEST		LIMITS	ACTUAL
4.1	Visual	No nicks, etc.	ok CA 1
4.2	Manual Actuation	-	ok CA 1
	4.2.1 Detent	-	ok CA 1
	4.2.2 Locking	-	ok CA 1
4.3.	Purge Operation	165.9– 174.6* L.P.M. 150 157	indicated 153 LPM actual 169.8 LPM
4.4	Relief Operation		
	4.4.1 Cracking Pressure	4.5 PSIG. min.	4.5 PSIG
	4.4.2 Full Flow	79.8 LPM* min. 70	indicated 64 LPM * actual 72.9 LPM *
	4.4.3 Reseat Pressure	4.5 PSIG. min.	4.47 PSIG *
4.5	Leakage		
	4.5.1 Relief Position	) 1.5 scc/min	0 scc/min
	4.5.2 Closed Position	) Max.	0 scc/min
4.6	Weight	140 grams max	88 grams
		quality	CA 1

* Test results indicated by asterisks exceed specification parameters.
Unit is submitted, subject to customer approval. CA 1

* 1. These flow rates are calculated for ambient pressures of 14.2 PSIA and temperatures of 70 and are equivalent to the flows stated in "Exhibit B" of NAS9-7646.

2. Correct flow meter readings as follows:

   a.) for test of 4.3

   Actual LPM = Indicated LPM (1.11)

   b.) for test of 4.42

   Actual LPM = Indicated LPM (1.14)

CARLETON CONTROLS CORPORATION

SPEC. NUMBER	REVISION LETTER	PAGE
CFT 428		6

DATA SHEET

CCC P/N 2098 003 - 3 Tested By R. Karlinski

S/N 2 Date 9/30/69

TEST		LIMITS	ACTUAL
4.1	Visual	No nicks, etc.	ok (CA 1)
4.2	Manual Actuation	-	ok (CA 1)
	4.2.1 Detent	-	ok (CA 1)
	4.2.2 Locking	-	ok. (CA 1)
4.3.	Purge Operation	165.9– 174.6* 150 157	indicated 152 LPM actual 168.7 LPM
4.4	Relief Operation		
	4.4.1 Cracking Pressure	4.5 p.s.i.g. min.	4.56 PSIG
	4.4.2 Full Flow	79.8 LPM* min. 70	indicated 71 LPM actual 80.9 LPM
	4.4.3 Reseat Pressure	4.5 p.s.i.g. min.	4.55 PSIG
4.5	Leakage		
	4.5.1 Relief Position	) 1.5 scc/min	0 scc/min
	4.5.2 Closed Position	) Max.	0 scc/min
4.6	Weight	140 grams max	88 grams
		quality	(CA 1)

* 1. These flow rates are calculated for ambient pressures of 14.2 PSIA and temperatures of 70 and are equivalent to the flows stated in "Exhibit B" of NAS9-7646.

2. Correct flow meter readings as follows:

   a.) for test of 4.3

   Actual LPM = Indicated LPM (1.11)

   b.) for test of 4.4.2

   Actual LPM = Indicated LPM (1.14)